UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF INTELLIGENT DISTRIBUTED TEMPERATURE MONITORING SYSTEM

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By

ABDUASSLAM AHMED ALI

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

February 2001

TO MY FAMILY

TO MY FRIENDS

TO THOSE WHO GAVE ME A HAND

TO YOU

I DEDICATE THIS THESIS

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science.

DEVELOPMENT OF INTELLIGENT DISTRIBUTED TEMPERATURE MONITORING SYSTEM

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February 2001

Chairman: Samsul Bahari Mohd Noor, Ph.D.

Faculty: Engineering

Distributed sensors could be used in a temperature monitoring system to track the change in temperature in a laboratory or any other room. The temperature monitoring system can be made intelligent by integrating it with a dialing system that warns against the unwanted temperatures that exceed some predefined limits. Such a system could be utilized in places where the temperature plays an important role. Tissue Culture laboratory is one of the laboratories that could get advantage of this system.

Tissue culture laboratory has a large number of tissue samples of various plants. Those tissue samples have to be kept in a specific range of temperature. Researchers need to maintain the temperature within the limits by adjusting the air conditioner to the required temperature. However, there might be a failure in the air conditioner due to lack of gas or thermostat malfunctioning. Temperature in that case will rise or drop and goes beyond the wanted limits. This problem might happen in the working

time hours or off time when nobody is around to notice the change in temperature. Accordingly, a need of a remote alarm system is of great importance to warn the related person for the situation.

This thesis deals with this problem and provides a system that monitor the temperature of the rooms and make emergency call to a pre-programmed number in case of temperature rise or drop out of a predefined range. Development of this system is divided into two main tasks. The first task is to develop a system that reads the temperature of the rooms and passes it to the microcontroller's analog to digital inputs. Then, it displays the temperatures on a computer's monitor. The second task is to develop a dialing system that dials a specified number in case the temperature exceeds limits of 29°C to 31°C. Motorola MC68HC11 is programmed to monitor the temperature and automatically dial the pre-programmed telephone number.

A complete system was developed in this work to measure the temperature and make emergency calls. It was tested and found to work properly. This work is of a major benefit because of the technique of using a dialing system as an alarm of temperature. It is a remote monitoring and alarming system.

It can be concluded that this system could be used in many applications where the need of remote sensors and alarming system is needed. Some changes and improvements can be added as required by each application.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN SISTEM PEMANTAUAN SUHU BERSELERAK YANG PINTAR

Oleh

ABDUASSLAM AHMED ALI

Februari 2001

Pengerusi: Samsul Bahari Mohd Noor, Ph.D.

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Pengesan yang berselerak boleh digunakan dalam sistem pemantauan suhu untuk mengesan perubahan suhu di dalam sesebuah makmal atau bilik. Dalam masa yang sama, sistem pemantauan suhu boleh dijadikan pintar dengan mengintegrasikan sistem yang boleh mendail untuk memberi amaran apabila suhu terkeluar dari julat yang telah ditentukan. Sistem sebegini boleh digunakan sekiranya suhu memainkan peranan yang penting. Makmal kultur tisu adalah salah satu makmal yang boleh memenafaatkan sistem ini.

Makmal mengkultur tisu mempunyai sebilangan besar contoh tisu untuk pelbagai jenis tumbuhan. Contoh tisu-tisu ini perlu disimpan dalam suatu julat suhu yang spesifik. Para pengkaji perlu mengekalkan suhu tersebut dengan mengawal penghawa dingin kepada suhu yang ditetapkan. Walaubagaimanapun, mungkin terdapat kebarangkalian kerosakan penghawa dingin akibat kekurangan gas atau

kerosakan termostat. Oleh yang demikian, suhu mungkin akan menurun atau melebihi tahap suhu yang dikehendaki. Masalah demikian mungkin berlaku dalam waktu bertugas atau rehat di mana tiada sesiapa yang akan mengesan perubahan dalam suhu. Justeru itu, keperluan untuk memiliki suatu sistem penggera jarak jauh untuk memberi amaran kepada individu yang terbabit adalah amat penting.

Tesis ini mengatasi masalah sedemikian dengan membekalkan suatu system yang dapat mengawal suhu bilik dan membuat panggilan kecemasan kepada nombor telefon yang ditentukan sekiranya berlaku kes perubahan suhu pada julat suhu yang ditetapkan. Pembangunan sistem ini dibahagikan kepada dua tugasan yang utama. Tugasan pertama adalah untuk membangun suatu system yang boleh membaca suhu bilik yang mana akan disalurkan kepada pengawal mikro analog kepada input digital. Seterusnya, ia akan memaparkan suhu pada monitor komputer. Tugasan kedua adalah membangun suatu sistem pengdialan yang dapat memanggil nombor yang ditetapkan sekiranya berlaku kes keterlampauan julat suhu 29°C sehingga 31°C. Motorola MC68HC11 telah diaturcarakan untuk mengawal suhu dan memanggil nombor telefon yang telah ditetapkan secara automatik.

Suatu sistem yang lengkap telah dibina untuk tesis ini untuk mengukur suhu dan membuat panggilan kecemasan. Sistem ini telah diuji dan didapati berfungsi dengan betul. Hasil kerja ini membawa kelebihan yang utama kerana ia menggunakan teknik sistem pemanggilan sebagai penggera suhu. Ia juga merupakan sistem penggera dan pengesan jarak jauh.

Sebagai kesimpulan, sistem ini juga boleh digunakan untuk pelbagai aplikasi yang memerlukan pengesan jarak jauh dan sistem penggera. Penyesuaian dan pembaikan kepada sistem boleh dilakukan seperti mana yang diperlukan oleh setiap aplikasi.

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Finally, my deepest and most sincere thanks to my family members, for their endless love, encouragement and moral support.

I certify that an Examination Committee met on 9th February 2001 to conduct the final examination of Abduasslam Ahmed Ali on his Master of Science thesis entitled "Development of Intelligent Distributed Temperature Monitoring System" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Name: Abduasslam Ahmed Ali

Date: 14 February, 2001

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LIST OF SYMPOLS AND ABBREVIATIONS

A	:	Ampere.
A	:	Cross sectional area.
ADC	:	Analog to digital converter.
ADCTL	:	Analog to digital control register.
ADR1-4	:	Analog to digital result registers.
ALU	:	Arithmetic logic unit.
A/D	:	Analog to digital.
BCD	:	Binary coded decimal.
C	:	Celsius.
C	:	Capacitance.
c	:	Specific heat capacity.
C_P	:	Specific heat capacity at constant pressure.
C_V	:	Specific heat capacity at constant volume.
CPU	:	Central processing unit.
D	:	Decimal value of digital output word.
DSS	:	Digital storage oscilloscope.
DTMF	:	Dual-tone multifrequency.
DTS	:	Distributed temperature sensors.
e	:	Electron charge.
e.m.f	:	Electromotive force.
f	:	Frequency.
FDM	:	Frequency division multiplexing.
I	:	Current.
i	:	Diode current, transistor current.
i_e	:	Emitter current.
i_s	:	Diode saturation current.
IC	:	Integrated Circuit.
i_c	:	Transistor collector current.
I/O	:	Input/Output.
K	:	Kelvin.
κ	:	Thermal conductivity.
k	:	Boltzmann's constant.
L	:	Length.
L	:	Inductor.
L_0	:	Length at reference temperature.
LC	:	Loop control.
LCD	:	Liquid crystal display.
LSB	:	Least significant byte.
M	:	Mach number, gain or slope.
m	:	Meter.
m	:	Mass.
mm	:	Millimeter.
n	:	Excited mode number, number of bits.
nm	:	Nanometer.
OTDR	:	Optical time domain reflectometry.
PC	:	Personal computer.
PI	:	Proportional-Integral controller.
Q	:	Amount of heat.

q	:	Electrical charge.
P_A	:	Seebeck coefficient of metal A.
P_B	:	Seebeck coefficient of metal B.
P_S	:	Seebeck Coefficient.
R	:	Resistance.
R_L	:	Load resistor.
R_T	:	Thermal resistance.
RAM	:	Random access memory.
r.m.s	:	Root mean square.
SAW	:	Surface acoustic wave.
SPI	:	Serial peripheral interface.
SPST	:	Single-pole single-throw.
T	:	Temperature.
T_0	:	Temperature of gas at rest.
T_T	:	Total temperature of moving gas.
TCR	:	Temperature coefficient of resistivity.
TDM	:	Time division multiplexing.
V	:	Voltage.
V_{be}	:	Transistor base to emitter voltage.
V_n	:	Thermal noise voltage.
∇	:	3-d vector gradient operator.
Δf	:	Frequency band-width
ΔV	:	Thermoelectric potential
α	:	Linear temperature coefficient of expansion.
β	:	Material constant of a thermistor.
λ	:	Wavelength.
τ_d	:	Delay time.
Φ	:	Phase shift.

CHAPTER 1

INTRODUCTION

The temperature on earth varies over the approximate range –60 to +60°C and although man can survive extremes of temperature, to live comfortably and work efficiently he needs an environmental temperature of about 20°C. The requirement therefore exists to control the temperature inside a wide variety of buildings and vehicles in order to counteract the effect of wide-ranging cycle and random external temperature deviation.

Plants as living creatures also need a suitable environmental temperature to grow in a good situation. Keeping temperature in specific limits for plants is of great benefit in order to test the effect of temperature on them. The effects of temperature can be considered on different levels of organization, from molecules and cells to the whole organism. The physiological processes in an organism depend on a series of reactions on lower level, where each reaction is characterized by its own temperature coefficient valid in a specific temperature range. The temperature of the plant is determined by its exchange of energy with the environment. The exchange can, for instance, be expressed in an energy balance of the leaf.

Due to the effect of temperature changes on plant growth and life, tracing the temperature of plants was needed to avoid any effects that might happen because of temperature change.

1.1 Objective of the Thesis

The purpose of this thesis is to develop an intelligent system that measures room temperature and display the average or distributed temperature reading on a computer monitor. The system also makes emergency calls to a specified number when the temperature exceeds a predefined limit. This system is controlled by Motorola 68HC11 microcontroller.

1.2 Thesis Layout

This thesis is divided into some chapters. Each chapter has a specific approach. The chapters are classified as introduction, literature review, methodology, results and discussion and the last is the conclusion and future work.

The first chapter is the introduction. It gives a brief information about the whole work and the goal of every section in it.

The second chapter is the literature review. It discusses some of the background ideas and works that dealt with temperature sensors and measurement and microcontroller applications. A description of tissue culture laboratory, as an example which require distributed temperature measurement system, is also included.

The third chapter is the methodology. It discusses the method followed to develop the system and the calculations needed. It shows how the temperature measurement system was established and connected to the microcontroller and how the microcontroller can make an emergency call in case the temperature goes beyond the specified limits.

The forth chapter is the results and discussion. The results obtained by this work are discussed in this chapter. It shows the way that the results were dealt with and how the program can be used successfully.

The fifth chapter is the conclusion and future work. This chapter shows how the system is properly working and how to improve it in the future for better results and quality.

The system was tested and found to be working satisfactorily and the goal has been achieved. However, improvement still can be made to this system as discussed in the fifth chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Temperature measurement was one of the earliest areas of metrology, and its use in control and instrumentation is significant. For control purposes, any temperature changes (except in special circumstances) are considered to occur slowly. Thus sampling rates are often as low as 0.05 Hz (20 s sample period) and do not present severe acquisition problems. Instruments for temperature measurement can be classified as mechanical, electrical or physical.

The mechanical devices are principally expansion-based and the physical devices use optical pyrometry. The electrical methods are mainly either thermoelectric or resistive, although some newer techniques employing semiconductor effects are becoming common. (George, 1988)

2.2 Commonly Arising Industrial Temperature Measurement Problems

Many application-dependent problems arise because of the physical configuration of a particular process. Some commonly arising features that need non-routine consideration are:

1. The surface temperature of a solid (perhaps a solid that is in rapid motion) needs to be measured.
2. The average temperature in a region needs to be measured accurately.
3. The temperature of a moving gas needs to be measured.
4. The internal temperature within an impenetrable massive solid needs to be measured.

2.2.1 Measurement of Surface Temperature

The measurement of surface temperature of solids (metallic, non-metallic, rough, smooth, flat, curved, stationary, moving) requires special techniques. Applications arise in the paper, textiles and foil industries.

The direct approach is to use special thermocouples of low thermal mass, matching the shape of the surface to be measured, and to use spring pressure to ensure good thermal contact between thermocouple and surface.

A second approach is to fix a small enclosure that produces near black-body conditions over the surface to be measured and then to use an infra-red sensor to monitor the radiation level and to relate this to surface temperature.

Another approach is to use a device such as the Hartmann & Braun thermo-vortex generator, the 'thermoturbolator' as shown in Figure 2.1. The thermoturbolator is a non-contact device that uses forced convection from the surface of interest to a thermocouple positioned close to the surface. A fan produces a vortex